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EFFICACY OF DORMANT SEASON HERBICIDE APPLICATION ON CONTROL OF JAPANESE HONEYSUCKLE (*LONICERA JAPONICA*) FOR HABITAT RESTORATION IN KENTUCKY

Jason L. Weese
University of Kentucky, zeb.weese@yahoo.com

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Jason L. Weese, Student

Dr. Michael J. Lacki, Major Professor

Dr. David Wagner, Director of Graduate Studies

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THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the College of Agriculture, Food and Environment at the University of Kentucky

By

Jason L. Weese

Lexington, Kentucky

Director: Dr. Michael J. Lacki, Professor of Forestry

Lexington, Kentucky

2015

ABSTRACT OF THESIS

EFFICACY OF DORMANT SEASON HERBICIDE APPLICATION ON CONTROL OF JAPANESE HONEYSUCKLE (*LONICERA JAPONICA*) FOR HABITAT RESTORATION IN KENTUCKY

Kentucky's disappearing native grassland communities provide habitat for native flora and fauna. A study was conducted to compare the efficacy of herbicides in control of the invasive Japanese honeysuckle (*Lonicera japonica*) applied at times when most native species are dormant. Six herbicide mixtures (glyphosate, glyphosate + imazapyr, glyphosate + imazapic, imazapyr, triclopyr + difluphenzopyr, and metsulfuron + difluphenzopyr) were applied in three seasons to assess the effect of application timing of each mixture on honeysuckle control. Herbicides were applied with a CO^2 pressurized sprayer at three sites in a randomized complete block design. Pretreatment sampling indicated that Japanese honeysuckle constituted over 70% of plant cover at the study sites. Post-treatment sampling was conducted 60 days, 180 days, 420 days, and 540 days after the final application. All mixtures decreased percent cover of honeysuckle with varying effectiveness. After 540 days over 74% of plant cover in all plots were species other than Japanese honeysuckle. Results indicate that the glyphosate, imazapyr, and metsulfuron + difluphenzopyr mixtures are particularly effective at controlling Japanese honeysuckle when applied at any time between October and April with suitable temperatures. Many native grasses and broadleaf forbs not found during pretreatment sampling also emerged post-treatment, either benefiting from application timing or indicating herbicide tolerance.

KEYWORDS: herbicide, restoration, invasive species, Japanese honeysuckle, habitat

Jason L. Weese

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By

Jason L. Weese

Dr Michael J. Lacki
Director of Thesis

Dr David Wagner
Director of Graduate Studies

3/26/2015
Date

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Introduction

An invasive species is defined as "a nonindigenous species that spreads from the point of introduction and becomes abundant" (Richardson et al. 2000). These species often pose serious threats to the native biodiversity of natural areas, changing overall ecological function and species composition (Randall 2001; Vitousek et al. 1997; Wilcove and Chen 1998). Invasives may form monocultures that monopolize resources and crowd out native species from their habitat (Evans 1982). According to the "Fluctuating Resource Availability" hypothesis, areas most susceptible to invasion by species adapted for quick colonization, i.e., those that lack natural inhibitors, are those systems prone to disturbance, such as by fire or grazing (Davis et al. 2000).

Small natural grassland systems are prone to disturbance and therefore invasion, and they are already in serious decline due to habitat loss and fragmentation caused by anthropogenic alterations (Noss et al. 1995). Less than 0.1% of the natural grasslands in the United States are intact, and most of these are in small patches of just a few acres (Sampson and Knopf 1994; Yahn 2014). In Kentucky, natural grasslands provide habitat for over 60% of the rare plant communities monitored by the Kentucky State Nature Preserves Commission (Taylor 1995).

Japanese honeysuckle (*Lonicera japonica*) is recognized as one of the most aggressive exotic invaders in the eastern United States due to its ability to crowd out or smother other species and monopolize resources (NISC 2004). Although the Kentucky Exotic Pest Plant Council (KY-EPPC) recognizes nearly 200 invasive species as problems for ecosystems, ecological impacts vary in severity by species. The KY-EPPC designates Japanese honeysuckle as a "severe threat," which is defined as an "exotic plant species which possess characteristics of invasive species and spread easily into native plant communities and displaces native vegetation; includes species which are or could become widespread in Kentucky" (Kentucky EPPC 2013). This category is reserved for the most ubiquitous and damaging invasive species in the Commonwealth, particularly those that threaten Kentucky's natural areas. The Southeast Exotic Pest Plant Council has verified Japanese honeysuckle in 119 of Kentucky's 120 counties and 43 states, although it is likely present in every county and state (Figures 1 and 2, EDDMaps 2014).

Figure 1. States with Japanese honeysuckle, 2014.

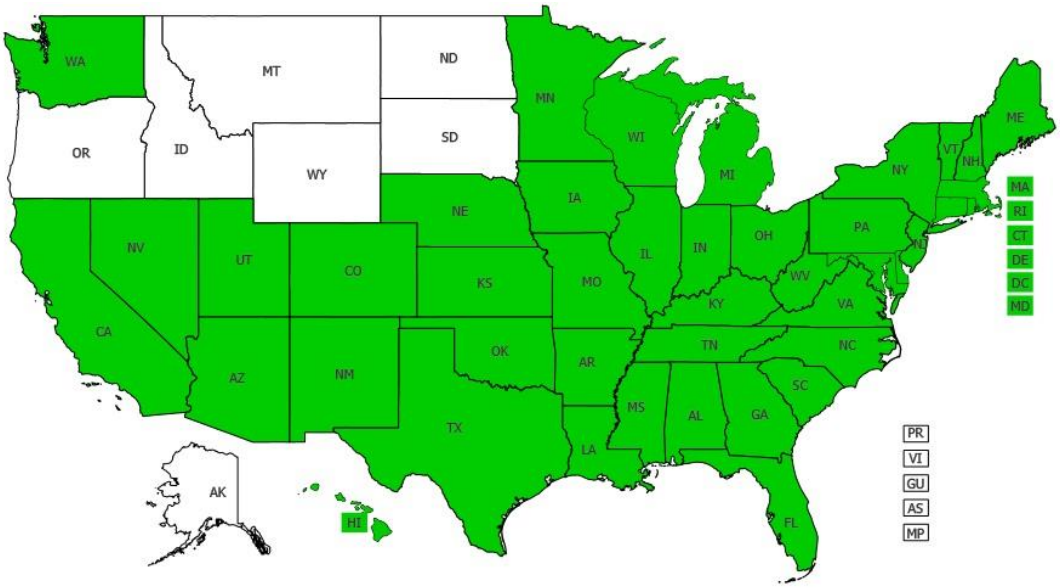
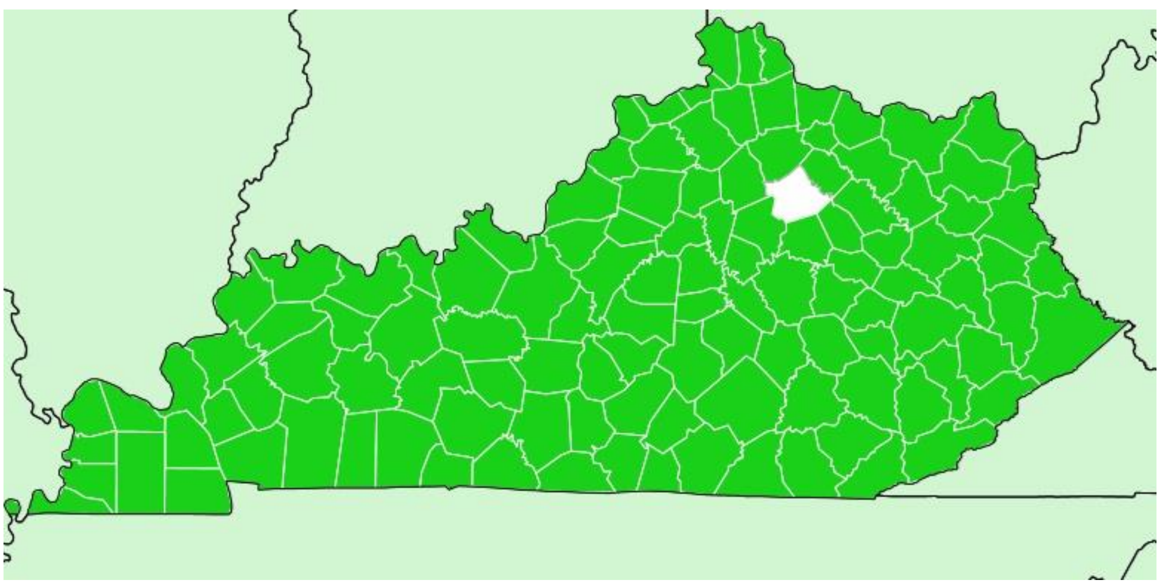


Figure 2. Kentucky counties with Japanese honeysuckle, 2014.



Ecology of Japanese Honeysuckle

Japanese honeysuckle is a southeast Asian native, naturally found along roadsides and sparsely vegetated forests under 1500 m in elevation (Zheng et al. 2004). It was first introduced to North America from Asia in 1806 as an ornamental plant, and is still widely available from the horticulture industry. Japanese honeysuckle's invasiveness is due, in part, to its ability to vigorously resprout after the aboveground vegetation (leaves and stems) have been removed following herbivory or cutting (Scheirenbeck 1994; Schweitzer and Larson 1999). Unfortunately, many game biologists have traditionally promoted Japanese honeysuckle as wildlife forage, even recommending its cultivation (Dyess et al. 1994; Handley 1945; Segelquist et al. 1976; Sheldon and Causey 1974). Japanese honeysuckle grows aggressively; each individual vine is capable of growing 10 meters per year (Pelczar 1995). Although Japanese honeysuckle thrives in open areas, it is somewhat shade tolerant and does well at forest edges; it will often lurk in sunny openings or edges for years and exploit new openings in the canopy created by storms or other disturbances to colonize the forest interior (Yates et al. 2004). Although most of the threat posed by Japanese honeysuckle to ecosystems is simple out-competition of native species, it also has the potential to further impact native plants through secretion of allelopathic compounds which alter soil chemistry, particularly when honeysuckle leaves are present in the litter layer (Skulman et al. 2000).

Management Strategies

Control of invasive species such as Japanese honeysuckle is becoming more important to land managers responsible for protecting and restoring the biodiversity of natural areas. The Society for Ecological Restoration (SER) defines restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SERS 2002). Reductions in invasive plant species populations have shown to increase native biodiversity and productivity (Price and Weltzin 2003). Other research has investigated non-chemical eradication or control methods and found them to be ineffective or impractical due to the dense mats formed by the rhizomes of Japanese honeysuckle. Cutting, pulling or burning the aboveground growth does not kill the plant, and in many cases stimulates even denser regrowth the following year. Similarly, mowing is an ineffective control method, stimulating growth and encouraging formation of dense, albeit shorter, mats. For example, in one study honeysuckle mowed in February formed a dense 20-cm tall mat within two months and 60-cm tall mat 21 months later (Stransky 1984).

While prescribed burns have proven effective in controlling many invasive species, fire removes the aboveground growth yet stimulates Japanese honeysuckle in much the same way as mowing (Munger 2002). In a Texas study, a February burn removed all above ground foliage but left rhizomes underground to subsequently resprout (Stransky 1984). In a North Carolina study, fire reduced honeysuckle coverage by 80%, but the species resprouted and remained dominant the following year (Barden and Matthews 1980). These studies indicate that only those methods that killed the belowground parts of the plant were effective in Japanese honeysuckle control.

Overview of Herbicides

Herbicide use is one of the most practical strategies for controlling many exotic plant invasions (Miller 2003). Herbicides are the predominant and most effective method for controlling Japanese honeysuckle invasions because they effectively target the persistent stolons and rhizomes in the soil organic layer (Prine and Starr 1971; Tu et al. 2001). While land managers rarely take an “all or nothing” approach to invasive species control, eradication is the ultimate goal, and can be a realistic goal when dealing with small populations of invasives (Simberloff 2003). However, natural area managers face a dilemma in selecting herbicides for honeysuckle control – how do you control honeysuckle while protecting habitat for native plants (Munger 2002)? Because Japanese honeysuckle actively grows in the winter until temperatures drop below -1°C in the southeastern United States, when most native species are dormant, it may be possible to control Japanese honeysuckle during the dormant season and avoid damage to existing broadleaf species while simultaneously releasing native species to germinate from the seedbank (Carter and Teramura 1988a). If this strategy is successful land managers could control Japanese honeysuckle populations while minimally affecting native species.

Chemical control of Japanese honeysuckle invasions has focused on using foliar herbicide applications. Foliar applications sometime reduce the density of above ground leaves and stolons briefly without completely killing the plant's rhizomes. In this case, new growth the following season can even exceed the original coverage prior to herbicide application (Prine and Starr 1971). Several studies found two seasons of low dose herbicide treatment are most effective for managing Japanese honeysuckle but still do not achieve adequate control over the long term (McLemore 1981; Miller 2003).

Among various herbicides tested for Japanese honeysuckle control, glyphosate has shown the most promise. Glyphosate is a systemic, enzyme inhibitor (it inactivates an enzyme that is critical to the synthesis of three amino acids) with very little soil activity (soil half-life 47 days), that is active to some extent on all plant species (Gover 2000). It is relatively inexpensive at $16-26 per gallon (Ferrell and Sellers 2014). Glyphosate phototoxicity differs seasonally and winter applications are less effective than those applied in other seasons due to lower photosynthetic activity (Neal and Skroch 1885). However, honeysuckle leaves are physiologically active during all seasons in the southeast (Carter and Teramura 1988b). Regehr and Frey (1988) indicated that October applications of glyphosate at concentrations of 0.75% and 1.5% were equally effective in killing honeysuckle with a 99% reduction in coverage by April and with very little resprouting at the completion of the 30-month study. December applications were much less effective, 68% mortality at the 0.75% rate and 86% mortality at 1.5% (Regehr and Frey 1988). All spraying occurred after defoliation to minimize impact on native plants. Resprouting was much greater after the December treatments than the October treatments (Regehr and Frey 1988). The study indicated that application before the first killing frost was more effective than application later in the season, and other reports similarly recommend application before the temperature drops below 25° C for the first time during the season (Nyboer 1992). July applications of glyphosate at 6.72 kg/ha resulted in 85% control after one growing season, and 80% control after two growing seasons (McLemore 1981). An August application of 2.2 kg/ha of glyphosate controlled 83% of actively growing honeysuckle (Younce and Skroch 1989).

The imidazolinone herbicides, such as imazapyr and imazapic, have been used effectively to reduce competition from exotic species and promote establishment of native species, although imazapyr has been shown to limit recruitment of native seedlings

(Masters et al. 1996, Beran et al. 2000, Washburn and Barnes 2000, Masters et al. 2001, Washburn et al. 2002). Imazapyr also has potential for honeysuckle control (Cain 1992). It is a systemic enzyme inhibitor (i.e., it inactivates an enzyme that is critical to the synthesis of three amino acids) that is very persistent in the soil (soil half-life 90 days), with selectivity largely determined by application rate although legumes are tolerant (Gover 2000). The cost of imazapyr at the time of this study was $65-360 per gallon, while imazapic was $325-475 per gallon (Ferrell and Sellers 2014). An 8 oz/acre (0.585 mL/ha) imazapyr application reduced Japanese honeysuckle coverage from 45% to 31% in one season (Cain 1992). Soil properties, including population of microorganisms in soil, temperature, moisture, organic matter, pH and soil particle distribution, effect the degradation of imidazolinone herbicides (Ayeni et al. 1998, Flint and Witt 1997, Masters et al. 1996). Imazapyr and imazapic can cause injury to native species and can reduce native species responses post-treatment (Fry et al. 1997, Masters et al. 1996).

Metsulfuron is another promising herbicide used for honeysuckle control. A systemic enzyme inhibitor (i.e., it inactivates an enzyme that is critical to the synthesis of three amino acids) with very low soil activity (soil half-life 30 days), it is primarily selective for broadleaf plants, although it may damage some grasses (Gover 2000). The cost of metsulfuron at the time of this study was $6-13 per dry oz (Ferrell and Sellers 2014). A May application of 4 oz/acre (0.28 kg/ha) resulted in 99% mortality of Japanese honeysuckle (Edwards and Gonzalez 1986). In other research, a June application of 1.5 oz/acre (0.105 kg/ha) appeared promising in reducing honeysuckle in a pine stand without excessively harming pine production (Yeiser 1999).

While research indicates that triclopyr is ineffective, some agencies still recommend its use in honeysuckle control, suggesting further study is needed (Dreyer 1988; Miller 2003). It is a systemic that mimics the activity of the plant hormone auxin with relatively little soil activity (soil half-life 46 days), and is mainly selective for broadleaf plants (Gover 2000). The cost of triclopyr at the time of this study was $58-100 per gallon (Ferrell and Sellers 2008).

There are no published studies of the effectiveness of diflufenzopyr on Japanese honeysuckle control. However, diflufenzopyr's efficacy against leafy spurge and Canada thistle was shown to be very variable with tank mix, but not rate (Lym and Deibert 2005). Difluphenzopyr is a systemic that mimics the activity of the plant hormone auxin, with moderate soil activity and selectivity for broadleaf plants (Gover 2000). At the time of this study the cost of difluphenzopyr was $45 per pound (Ferrell and Sellers 2014).

Other studies indicate the effect of application timing on other herbicides. Dichlorprop mixed with 2, 4-D at a 1.5% concentration resulted in 94% mortality when applied in October, but a December application yielded only 46% mortality. Thirty months after treatment, 14% of stems sprayed in October had resprouted and 75% of stems sprayed in December had resprouted (Regehr and Frey 1988). A June application of Sulfometuron applied at 3 oz/acre (0.219 L/ ha) yielded “unacceptable” control (Withrow et al. 1983).

Objectives

The objectives of this project were to evaluate the efficacy of the following herbicides on controlling Japanese honeysuckle: glyphosate, glyphosate + imazapyr, glyphosate + imazapic, imazapyr, triclopyr + difluphenzopyr, and metsulfuron + difluphenzopyr, and to evaluate the timing of herbicide application on Japanese honeysuckle control. Accordingly, I hypothesized that herbicide mixtures applied to Japanese honeysuckle while the plant is actively growing, but while most native plants are dormant, can control honeysuckle while minimally affecting native species.

Methods

Each herbicide mixture was applied once in three different seasons throughout the year to determine the effects of application timing on efficacy. The effectiveness of each mixture in controlling Japanese honeysuckle was compared to the effectiveness of the other mixtures, as well as the other fall, winter, and spring applications of the same mixture. Each application was replicated three times per herbicide per season to increase statistical significance. These mixtures were chosen based on results of previous studies in the literature as well as recommendations from herbicide manufacturers. The concentration for each mixture is found in Table 1, concentrations were determined by reviewing previous literature on these mixtures as well as consulting the herbicide labels for maximum legal application rate. Only non-restricted use herbicides were tested, as a practical management consideration; many natural areas use volunteers for invasive control which makes obtaining restricted use applicator certification impractical in many cases.

After deciduous trees defoliated in October 2004, each site underwent visual vegetative sampling to determine the percentage of total plant cover, percentage of Japanese honeysuckle cover, species richness, and cover of other species present (see Appendix I, Table A1). Initial Japanese honeysuckle coverage varied from 70% to 96%. Pretreatment data were used to determine how effective each herbicide is in reducing Japanese honeysuckle coverage by completion of the study, and to determine any other changes in the botanical composition of the plots as a result of herbicide applications.

After pretreatment sampling, each site was randomly laid out in 19 plots and marked with aluminum fence posts and flagging. For example, glyphosate was applied to one treatment plot in fall, another plot in winter, and a third plot in spring. Therefore, each site had 19 plots – six fall treatments, six winter treatments, six spring treatments, plus one control. See Figure 3 for general plot layout. Each study plot was 3 m by 9 m, dictated by the width of the 3-m boom on the pressurized CO_2 sprayer and the distance it takes for the sprayer to empty a 2 L bottle of mixture at 35 psi (241.3 kPa) at a normal walking speed of approximately 4.5 km/hour.

In late October, after the first frost but before the first "killing frost" (temperature below -4°C), each mixture was applied in three replications, one per site. The order of mixture application was chosen randomly in a randomized complete block design. The same procedure was repeated in January or February 2005 to assess winter applications. Winter application days were chosen based on climatological factors; herbicides lose effectiveness at temperatures below 15° C and wind speeds exceeding 8 km/hour, and most are not rainfast for at least 2 hours (Gover 2000). The final applications were conducted in early April 2005 to assess spring herbicide application before many native species are actively growing or blooming and, therefore, less likely to take up herbicide foliarly (see Appendix I, Table 2 for all application dates).

Following the Spring 2005 applications each site underwent visual vegetative sampling in Summer 2005, Fall 2005, Summer 2006, and Fall 2006 using a 0.3-m sampling frame quadrate dropped randomly in the center of each treatment plot five times to determine the changes in honeysuckle coverage and overall species composition in each plot (Bonham 1989). Sampling was limited to the center of the plot to reduce potential of interaction with the herbicide treatments on adjacent plots. A repeated measures analysis of variance using PROC MIXED with SAS® software version 9.1 for Windows (Little et al. 1996) and a mean comparison test were used to determine any differences in herbicide treatments and application timing. Differences in treatment means were identified using the least squares means procedure.

Pre-treatment Data and Site Descriptions

Due to the relatively large contiguous areas of dense honeysuckle required for this number of herbicide treatments, three sites were used: Hall's Prairie, a roadside natural area in Logan County, Kentucky; and, two highway right-of-ways managed by the Kentucky Department of Transportation, one in Shelby County and the other in Powell County (Figure 4). The Logan and Shelby sites are in the Interior Plateau physiographic region, while the Powell County site is in the Western Allegheny Plateau (Woods et al. 2002). All three sites were open fields bordering major highways, and were dominated by Japanese honeysuckle. Highway construction is associated with fill dirt brought from off-site, as well as invasive species establishment, so soil data were not considered (Rentch et al. 2005).

Adjacent areas were dominated by a mix of native early successional plants including eastern red-cedar (*Juniperus virginiana*), tall goldenrod (*Solidago altissima*), Canada goldenrod (*Solidago canadensis),* box elder (*Acer negundo*), blackberries (*Rubus spp.),* trumpet creeper *(Campsis radicans),* and blackeyed susan *(Rudbeckia hirta),* along with other non-native invasive species including teasel *(Dipsacus fullonum),* bull thistle *(Cirsium vulgare),* tall fescue *(Festuca arundinacea),* purple crownvetch *(Coronilla varia),* and poison hemlock *(Conium maculatum).*

The study site at Hall’s Prairie was situated on a $<5^{o}$ slope with no overstory cover. Pretreatment vegetation sampling showed that the Hall’s Prairie site averaged 81.7% Japanese honeysuckle cover per m^2 (SE = 9.1, n = 12). While the overall site was dominated by Japanese honeysuckle, the native tall goldenrod, *Solidago altissima*, did dominate two plots. The study site at Shelby County was situated on a $<5^{o}$ slope with no overstory cover. Pretreatment vegetation sampling showed that the Shelby County site averaged 95.8% Japanese honeysuckle cover per m^2 (SE = 1.8, n = 12). While the site was entirely dominated by Japanese honeysuckle, some plots contained scattered goldenrod, native milkweed (*Asclepias purpurascens)*, and non-native invasive crown vetch (*Coronilla varia*). The study site at Powell County was situated on a $<5^{o}$ slope with no overstory cover. Pretreatment vegetation sampling showed that the Shelby County site averaged 70.0% Japanese honeysuckle cover per m^2 (SE = 8.94, n = 12). This site had several plots with a substantial amount of crown vetch, as well as several blackberry bushes (*Rubus* spp.).

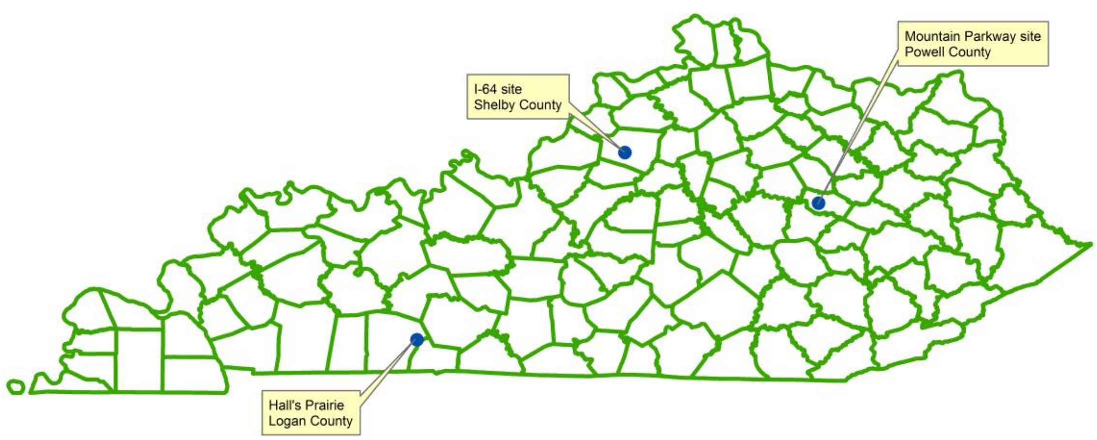
Table 1. Herbicide treatments by brand, active ingredient, and application rate.

Brand Name	Active Ingredient	Application Rate	Acid Equivalent
RoundUp Pro	glyphosate	2.0 gal/acre (18.7 L/ha)	6 a.e/acre (2.43 a.e./ha)
RoundUp Pro + Stalker	glyphosate	1.0 al/acre (9.35 L/ha)	3 a.e./acre (1.21 a.e./ha)
	imazapyr	0.125 gal/acre (1.17 L/ha)	0.375 a.e/acre (0.152 a.e./ha)
Stalker	imazapyr	0.25 gal/acre (2.34 L/ha)	0.75 a.e./acre (0.304 a.e./ha)
Journey	glyphosate	0.25 gal/acre (2.34 L/ha)	0.375 a.e/acre (0.152 a.e./ha)
	imazapic		0.187 a.e/acre (0.076 a.e./ha)
Remedy + Overdrive	triclopyr	0.125 gal/acre (1.12 L/ha)	0.5 a.e/acre (0.202 a.e./ha)
	difluphenzopyr	0.25 lbs/acre (0.28 kg/ha)	0.05 a.e/acre (0.020 a.e./ha)
Escort + Overdrive	metsulfuron	1.0 lb/acre (1.12 kg/ha)	0.6 lbs a.i./acre (0.243 a.i./ha)
	difluphenzopyr	0.25 lbs/acre (0.28 kg/ha)	0.05 a.e/acre (0.020 a.e./ha)

Note: treatments 2-6 also contain 0.25 gal/acre (0.383 L/ha) methylated seed oil as an adjuvant.

Figure 3. General plot layout of herbicide treatments at each site in Kentucky.

Figure 4. Map of Kentucky with study sites identified.



Results and Discussion

Across all herbicides there was no difference in application timing on Japanese honeysuckle control ($F=1.91$, $df=2$, $p=0.1515$); however, there was a difference in control of Japanese honeysuckle among different herbicide treatments ($F=502.71$, $df=6$, p<0.0001). The percent cover of live Japanese honeysuckle at all sites is provided for each post-treatment sample period (Table 2). After the second growing season and at the final sample period the fall applications of glyphosate, imazapyr, glyphosate + imazapic, and metsulfuron + difluphenzopyr plots had < 5% live Japanese honeysuckle; the triclopyr + difluphenzopyr and glyphosate + imazapyr plots had less dieback with just under 10% live Japanese honeysuckle (Figure 5). Similarly, winter applications of glyphosate, imazapyr, glyphosate + imazapyr, and metsulfuron + difluphenzopyr plots had < 5% live Japanese honeysuckle, while the triclopyr + difluphenzopyr and glyphosate + imazapic plots experienced less dieback with approximately 20% live Japanese honeysuckle (Figure 6). Finally, spring applications yielded similar results, with the glyphosate, imazapyr, and metsulfuron + difluphenzopyr plots once again having < 5% live Japanese honeysuckle while the glyphosate + imazapyr had >7%, glyphosate + imazapic at 20%, and the triclopyr + difluphenzopyr > 25% live Japanese honeysuckle (Figure 7). It is worth noting both glyphosate and imazapyr performed better individually than combined together. It is unclear whether this outcome was due to interactions between the chemicals or simply because the label rate for both was lower in the combined mixture (Table 1).

Across all herbicides there was a difference in application timing on percentage of other plant species present in each sampling period (F=6.39, df=2, p= 0.0022). There was also a difference in percentage of other species in each plot among the different herbicide treatments (F=79.51, df=6, p<0.0001). The percent cover of species other than Japanese honeysuckle at all sites is provided for each post-treatment sample period (Table 3). By fall 2006 all plots were >70% revegetated with species other than Japanese honeysuckle (Figures 8, 9, 10). The resulting composition was largely dependent on species available in the seedbank and/or in adjacent tracts. See Appendix III for post-treatment species list for each site. It should be noted that while the Shelby and Powell County highway right-of-way sites were largely invaded by other invasive species, such as crown vetch and poison hemlock, or early successional native, such as blackberries, the more natural Hall's Prairie also saw native species appear that were not seen in the pretreatment sampling, including purpletop (*Tridens flavus*), blackeyed susan (*Rudbeckia* *hirta*), and indiangrass (*Sorghastrum nutans*). Species richness indices were not calculated as there is evidence that species diversity is not a good indicator of the invasibility of sites, and highway disturbance corridors are particularly susceptible to invasions (Higgins 1999, Rentch 2005).

Conclusion and Management Considerations

This study demonstrated that applying high rates of several herbicide mixtures on Japanese honeysuckle during the dormant season can produce exceptional control for two years and shows potential for converting species-poor, honeysuckle-dominated fields to more diverse communities. Natural areas managers should consider chemically treating Japanese honeysuckle infestations between October and April on warm days. Overall, my findings suggest dormant-season herbicide applications are an effective means for reducing Japanese honeysuckle cover in natural areas without impacting other vegetation.

Results also suggest that rapid revegetation is possible following a dormant season herbicide treatment, but species composition will be site specific (Appendix III)**.** Establishment of other species quickly after herbicide treatment is important as bare ground tends to encourage the establishment of other invasive species (Adkins and Barnes 2013). Species richness was generally greater in herbicide treated plots compared to untreated plots, in some cases gaining four or five native species per plot. This supports previous research showing that eradication of undesirable vegetation is necessary for establishment of native plant communities (Wilson and Gerry 1995, Masters et al. 1996, Washburn et al. 1999, Barnes 2004). Species present in my study other than Japanese honeysuckle varied by site and treatment and ranged from other invasive species (e.g., poison hemlock, Canada thistle) to native grassland species (e.g., indiangrass, blackeyed susan), indicating that restoration of native species is highly site specific and dependent on species availability in the seedbank and adjacent or nearby areas.

The glyphosate, imazapyr, and metsulfuron + difluphenzopyr consistently controlled Japanese honeysuckle in all of the application seasons, with <5% of each plot containing Japanese honeysuckle in the final sampling period. Glyphosate offers the most attractive balance of effective honeysuckle control, subsequent revegetation, low soil activity, and cost ($24 - $70 / ac at my application rate). Metsulfuron + diflufenzopyr is a good choice to use if persistent resprouts occur as it has similar efficacy but higher cost ($320-432 per acre for metsulfuron and $9.50 per acre for difluphenzopyr at this application rate), as does imazapyr ($24 to $70 per acre at this application rate). It is important to note that all three of these herbicides are systemic enzyme inhibitors; because their mode of action is the same, switching between them will not reduce herbicide resistance on site. While this study indicates that application of glyphosate, imazapyr, or metusulfuron+difluphemzopyr performed better than the other mixtures in the dormant season, all of the herbicide treatments reduced Japanese honeysuckle cover two years after treatment relative to control levels and other species were established by the first growing season.

Natural areas managers spend a significant amount of labor and funds on managing invasive species, often a frustrating and seeming fruitless endeavor. Many spend countless hours removing one invasive only to see it resprout the following year or even see another invasive species take its place, what I often call "rotating the crops." Operating under staffing limitations and budget constraints, herbicides are often the cheapest and quickest way to deal with invasives, but many people dislike using chemicals due to perceived hazards to human health, water quality, wildlife health and other environmental concerns. Although this study is based on the premise that chemical control is the most effective and practical way to control Japanese honeysuckle, I share those concerns and do not personally advocate the casual use of these herbicides. Not only should herbicide label instructions be followed at all times, but any invasive species treatment program should be well thought out and designed to minimize chemical exposure to both the environment and the applicators.

In addition to the health and safety concerns with chemical treatments, natural areas managers are sometimes frustrated with the perceived lack of results from their control efforts. Unfortunately, many invasive control projects are short term; invasives are killed when the budget allows with no real plan to retreat any resprouts or new invasions. Without follow-up in subsequent years, perhaps in perpetuity, even areas that are aggressively treated in one season will become reinfested to a similar degree in just a few years without some retreatment. Using this study as a starting point, I only recommend chemically treating Japanese honeysuckle in the dormant season, and, if labor and funding are allocated, to retreat the same plots every second year until all signs of infestation are removed. If the infestation is reduced by 90% with each treatment then the time and funds spent on retreatment will decrease with every application, in addition to the volume of chemicals used. If the site is in a heavily disturbed area like the Shelby County and Powell County highway right-of-ways it may end up infested with yet another invasive species such as crown vetch or poison hemlock, in which case treatment may be a waste of time, funding, and chemical exposure. But on a less disturbed site, such as Hall's Prairie, the result will likely be a restored native natural area.

Table 2. Percent cover of Japanese honeysuckle per sampling period and treatment, all sites combined.

Sample Period*	Summer 05		Fall 05		Summer 06		Fall 06	
Treatments	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fall								
Control	96.33	(0.67)	91.67	(1.45)	94.33	(0.93)	92.67	(1.76)
Glyphosate	1.13	(1.13)	5.67	(4.70)	1.93	(0.67)	2.60	(0.81)
Gly+Ipic	1.53	(1.53)	11.00	(8.54)	6.33	(0.26)	4.67	(0.88)
Gly+Ipyr	4.47	(3.30)	11.00	(8.50)	8.80	(3.27)	8.33	(3.18)
Imazapyr	0.80	(0.61)	0.33	(0.33)	3.27	(1.27)	3.27	(1.49)
Mets+Diflu	0.67	(0.67)	1.67	(1.67)	1.00	(0.77)	1.60	(1.22)
Tri+Diflu	13.47	(4.04)	14.50	(3.67)	37.00	(10.74)	9.13	(1.74)
Winter								
Control	96.33	(0.67)	91.67	(1.45)	94.33	(0.93)	92.67	(1.76)
Glyphosate	2.60	(1.70)	2.13	(1.94)	7.33	(4.16)	1.47	(0.74)
Gly+Ipic	2.00	(2.00)	22.00	(9.71)	33.00	(6.71)	22.00	(6.11)
Gly+Ipyr	0.47	(0.47)	2.67	(2.67)	2.33	(0.93)	0.93	(0.52)
Imazapyr	0.00	(0.00)	4.00	(4.00)	6.00	(2.37)	3.60	(0.70)
Mets+Diflu	0.67	(0.67)	0.33	(0.33)	1.00	(0.45)	2.33	(1.45)
Tri+Diflu	34.13	(16.80)	22.67	(12.88)	48.67	(5.24)	19.27	(8.73)
Spring								
Control	96.33	(0.67)	91.67	(1.45)	94.33	(0.93)	92.67	(1.76)
Glyphosate	2.33	(1.45)	5.00	(4.51)	10.00	(1.61)	4.33	(0.88)
Gly+Ipic	0.00	(0.00)	14.33	(5.81)	14.67	(4.06)	19.67	(3.84)
Gly+Ipyr	0.00	(0.00)	2.67	(0.33)	3.47	(0.61)	7.33	(3.84)
Imazapyr	0.00	(0.00)	3.67	(3.18)	3.60	(2.49)	4.33	(1.76)
Mets+Diflu	0.00	(0.00)	1.33	(1.33)	0.33	(0.26)	1.13	(0.47)
Tri+Diflu	21.93	(5.50)	31.00	(13.65)	32.33	(10.64)	25.67	(10.73)

*For treatments means by sample period, n=3

Table 3. Percent cover of other species per sampling period and treatment, all sites combined.

Sample Period*	Summer 05		Fall 05		Summer 06		Fall 06	
Treatments	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fall								
Control	3.33	(0.88)	7.00	(2.65)	5.33	(1.45)	6.87	(1.74)
Glyphosate	22.00	(14.80)	68.00	(6.03)	76.73	(10.61)	96.27	(1.71)
Gly+Ipic	41.80	(12.10)	44.00	(17.09)	73.20	(3.90)	75.00	(2.52)
Gly+Ipyr	5.67	(2.33)	70.00	(11.59)	73.00	(6.51)	85.67	(6.64)
Imazapyr	21.27	(9.30)	80.33	(7.88)	66.73	(16.46)	82.33	(2.91)
Mets+Diflu	9.80	(4.92)	45.67	(11.84)	64.00	(19.09)	97.33	(0.88)
Tri+Diflu	40.87	(16.69)	65.50	(7.76)	51.00	(3.61)	84.00	(5.69)
Winter								
Control	3.33	(0.88)	7.00	(2.65)	5.33	(1.45)	6.87	(1.74)
Glyphosate	7.67	(4.26)	95.40	(1.40)	84.67	(9.94)	98.53	(0.74)
Gly+Ipic	1.67	(0.88)	27.00	(8.14)	54.00	(5.00)	75.33	(5.81)
Gly+Ipyr	3.67	(2.73)	54.33	(2.96)	73.20	(3.71)	98.40	(0.87)
Imazapyr	0.00	(0.00)	14.67	(5.61)	59.00	(6.24)	77.40	(4.40)
Mets+Diflu	0.00	(0.00)	84.67	(8.35)	74.67	(6.67)	96.20	(1.72)
Tri+Diflu	15.20	(8.33)	43.00	(17.62)	42.33	(8.01)	80.67	(8.67)
Spring								
Control	3.33	(0.88)	7.00	(2.65)	5.33	(1.45)	6.87	(1.74)
Glyphosate	10.13	(4.24)	64.33	(7.88)	77.33	(4.63)	93.67	(1.45)
Gly+Ipic	3.00	(3.00)	60.00	(10.07)	65.00	(13.86)	78.33	(2.73)
Gly+Ipyr	21.67	(4.06)	67.33	(5.55)	68.20	(10.28)	90.67	(2.60)
Imazapyr	0.33	(0.33)	55.00	(9.07)	58.00	(11.02)	81.33	(1.67)
Mets+Diflu	2.33	(2.33)	81.67	(5.24)	74.67	(1.76)	96.53	(1.78)
Tri+Diflu	22.33	(7.88)	57.87	(10.77)	57.67	(16.70)	74.33	(10.73)

*For treatments means by sample period, n=3

Figure 5. Percent cover Japanese honeysuckle after fall application, all sites combined.

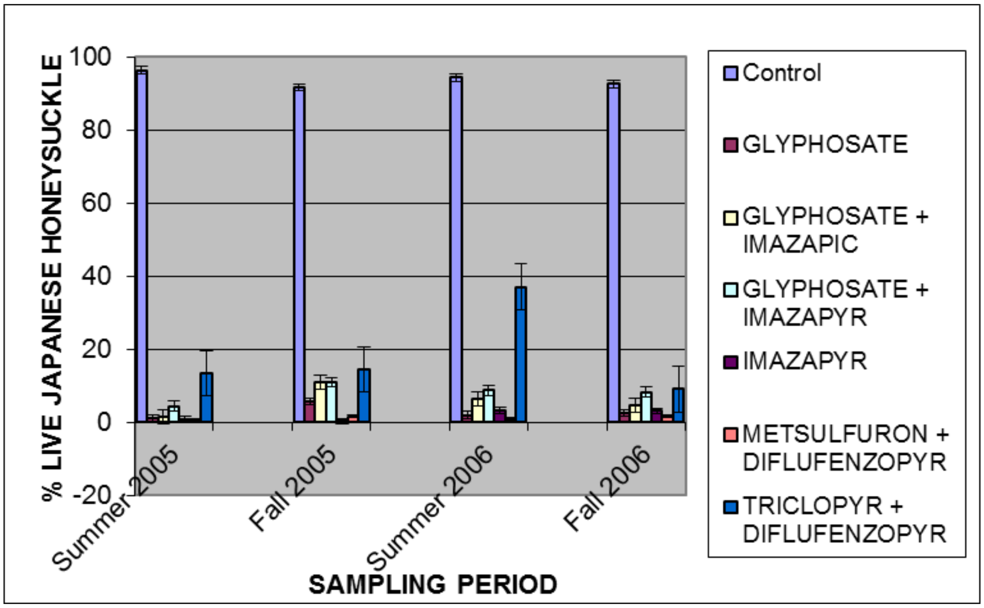


Figure 6. Percent cover Japanese honeysuckle after winter application, all sites combined.

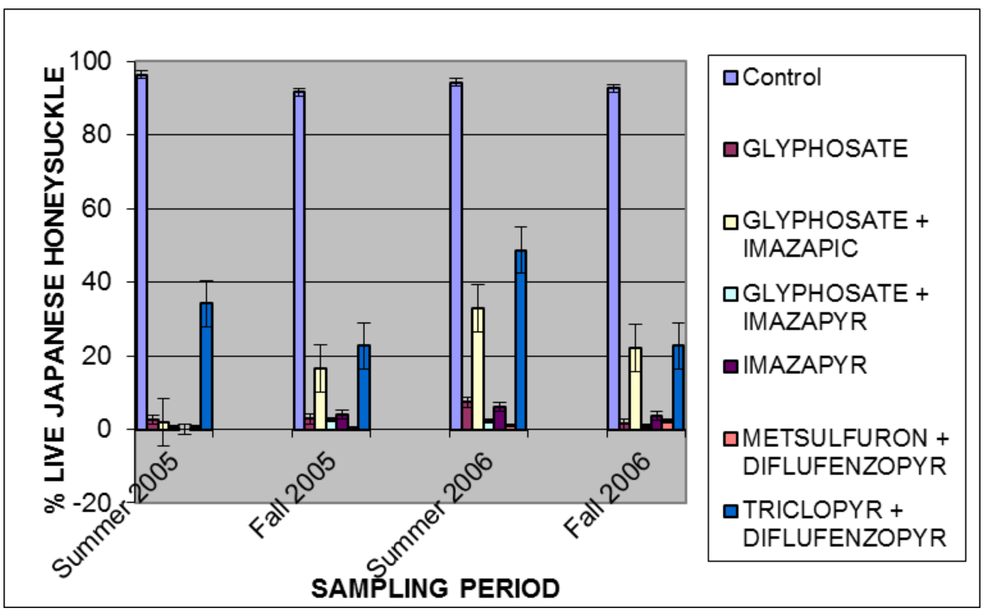


Figure 7. Percent cover Japanese honeysuckle after spring application, all sites combined.

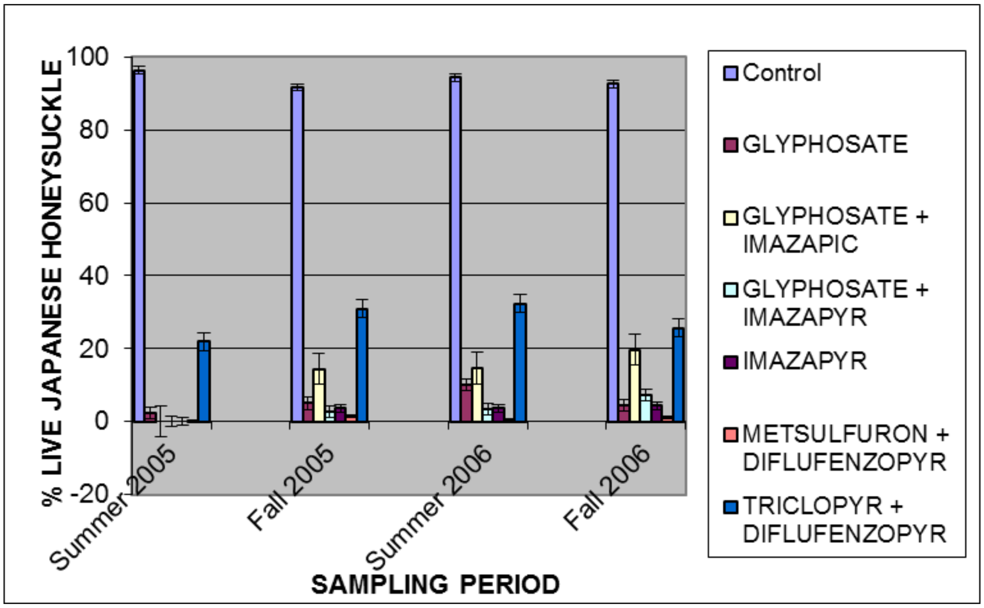


Figure 8. Percent cover other species after fall application, all sites combined.

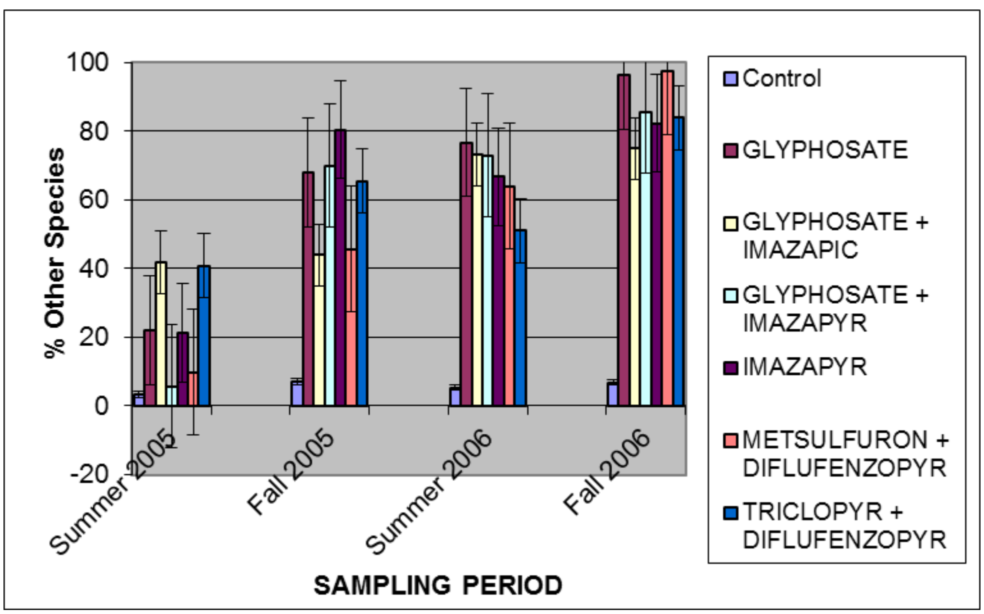


Figure 9. Percent cover other species after winter application, all sites combined.

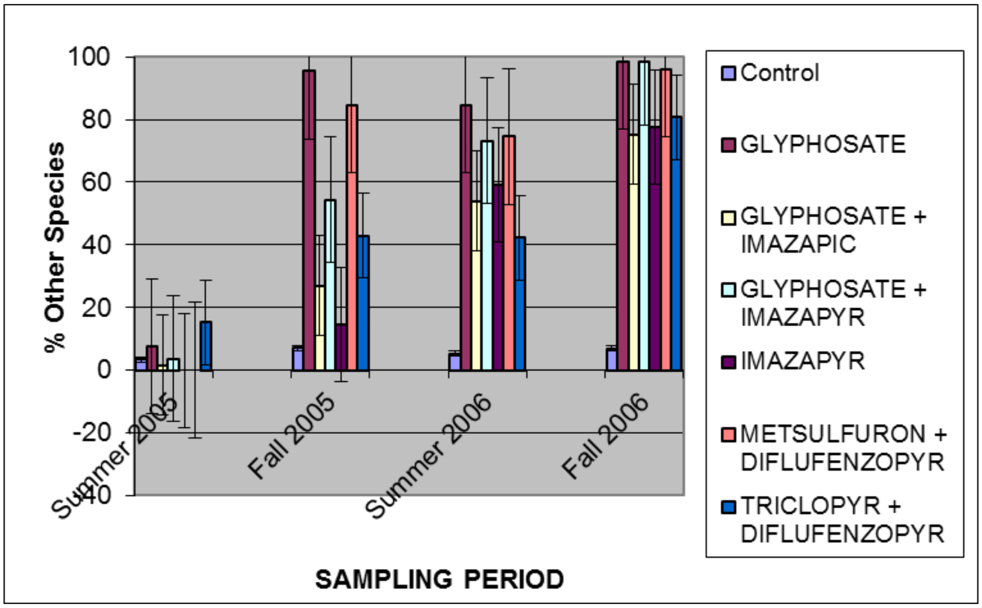
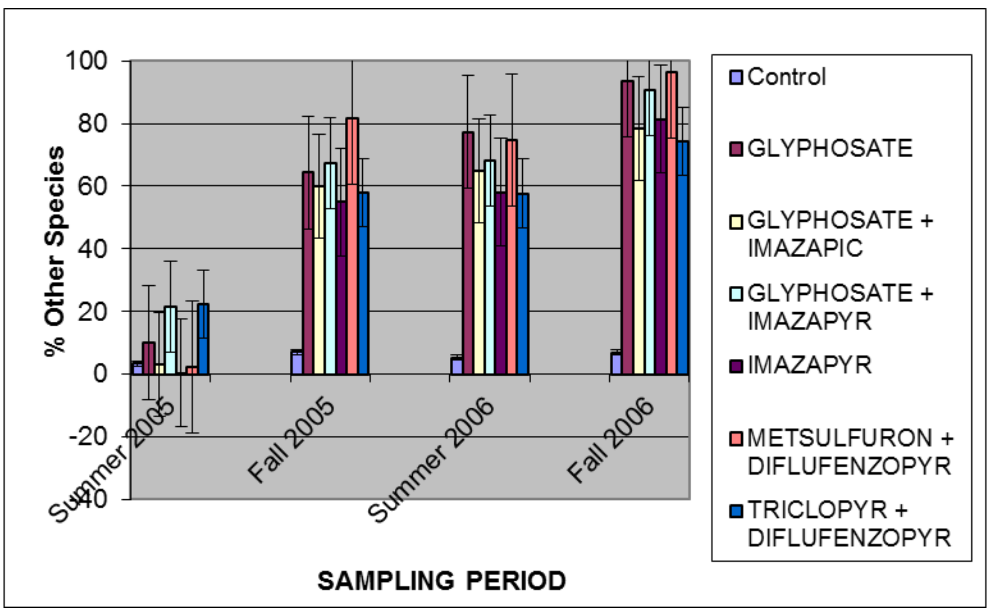


Figure 10. Percent cover other species after spring application, all sites combined.



Appendix I. Pretreatment information.

Table AI1. Pretreatment sampling of Japanese honeysuckle cover.

Date	Site	Mean % *Lonicera japonica**	Other Species Present
Oct 13, 2004	Hall's Prairie	81.67	*Solidago altissima*
Oct 20, 2004	Shelby County	95.83	*Solidago altissima* *Asclepias pururascens* *Coronilla varia*
Oct 24, 2004	Powell County	70.0	*Coronilla varia* *Rubus spp.*

*n=12

Table AI2. Dates Herbicide Applied

Date	Site	Application Period
Oct 20, 2004	Hall's Prairie	Fall 2004
Jan 6, 2005		Winter 2005
April 11, 2005		Spring 2005
Oct 25, 2004	Shelby County	Fall 2004
Feb 6, 2005		Winter 2005
April 11, 2005		Spring 2005
Oct 25, 2004	Powell County	Fall 2004
Feb 6, 2005		Winter 2005
April 10, 2005		Spring 2005

Appendix II. Percent cover Japanese honeysuckle by site.

Table AII.1. Mean percent Japanese honeysuckle cover at Hall's Prairie, Logan County, Kentucky.

Sample Period*	Summer 05		Fall 05		Summer 06		Fall 06	
Treatments	Mean	SE	Mean	SE	Mean	SE	Mean	SE
<u>Fall</u>								
Control	97	(2.0)	94	(2.9)	96	(1.9)	96	(2.4)
Glyphosate	0	(0.0)	0	(0.0)	2	(1.2)	2.6	(1.1)
Gly+Ipic	4.6	(2.3)	4	(2.4)	6	(1.0)	5	(2.2)
Gly+Ipyr	0.4	(0.4)	2	(2.0)	9	(4.3)	12	(4.6)
Imazapyr	0.4	(0.4)	0	(0.0)	5	(2.2)	5.4	(1.3)
Mets+Diflu	0	(0.0)	0	(0.0)	0	(0.0)	0.8	(0.5)
Tri+Diflu	18	(7.3)	19	(12.9)	45	(15.5)	12	(4.6)
<u>Winter</u>								
Control	97	(2.0)	94	(2.9)	96	(1.9)	96	(2.4)
Glyphosate	0	(0.0)	0	(0.0)	1	(1.0)	0	(0.0)
Gly+Ipic	0	(0.0)	16	(13.5)	33	(17.3)	34	(10.8)
Gly+Ipyr	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.0)
Imazapyr	0	(0.0)	0	(0.0)	4	(1.9)	5	(3.2)
Mets+Diflu	0	(0.0)	0	(0.0)	0	(0.0)	5	(1.6)
Tri+Diflu	9	(5.6)	6	(4.0)	40	(8.4)	1.8	(0.6)
<u>Spring</u>								
Control	97	(2.0)	94	(2.9)	96	(1.9)	96	(2.4)
Glyphosate	0	(0.0)	1	(1.0)	7	(2.5)	6	(1.6)
Gly+Ipic	0	(0.0)	25	(12.8)	23	(14.4)	18	(15.6)
Gly+Ipyr	0	(0.0)	2	(2.0)	5	(1.6)	9	(3.7)
Imazapyr	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.0)
Mets+Diflu	0	(0.0)	0	(0.0)	0	(0.0)	1	(1.0)
Tri+Diflu	31	(13.5)	6	(4.0)	58	(8.6)	17	(5.4)

*For treatments means by sample period, n=5

Table AII.2. Mean percent Japanese honeysuckle cover at Shelby County site, Kentucky.

Sample Period*	Summer 05		Fall 05		Summer 06		Fall 06	
Treatments	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fall								
Control	97	(2.0)	92	(4.1)	92	(4.1)	92	(3.4)
Glyphosate	0	(0.0)	15	(11.5)	3.4	(1.0)	4	(1.9)
Gly+Ipic	0	(0.0)	28	(15.9)	6	(1.9)	6	(1.0)
Gly+Ipyr	11	(3.3)	28	(8.5)	16	(4.8)	2	(2.0)
Imazapyr	0	(0.0)	0	(0.0)	0	(0.0)	4	(2.4)
Mets+Diflu	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Tri+Diflu	5.4	(3.8)	10	(5.0)	10	(5.0)	9.4	(2.5)
Winter								
Control	97	(2.0)	92	(4.1)	92	(4.1)	92	(3.4)
Glyphosate	5.8	(1.8)	6	(4.0)	18	(11.1)	2.4	(1.1)
Gly+Ipic	6	(1.9)	41	(10.3)	48	(12.4)	14	(2.4)
Gly+Ipyr	1.4	(1.0)	8	(3.7)	4	(2.4)	0	(0.0)
Imazapyr	0	(0.0)	12	(3.7)	12	(3.7)	3	(2.0)
Mets+Diflu	0	(0.0)	1	(1.0)	1	(1.0)	0	(0.0)
Tri+Diflu	66	(6.8)	48	(9.5)	62	(11.2)	28	(8.0)
Spring								
Control	97	(2.0)	92	(4.1)	92	(4.1)	92	(3.4)
Glyphosate	5	(3.9)	14	(5.1)	14	(5.1)	4	(2.4)
Gly+Ipic	0	(0.0)	5	(2.2)	5	(2.2)	14	(6.0)
Gly+Ipyr	0	(0.0)	3	(2.0)	3	(2.0)	0	(0.0)
Imazapyr	0	(0.0)	10	(5.2)	10	(5.2)	5	(2.2)
Mets+Diflu	0	(0.0)	0	(0.0)	0	(0.0)	2	(2.2)
Tri+Diflu	22.8	(11.2)	53	(4.9)	28	(11.6)	13	(4.1)

*For treatments means by sample period, n=5

Table AII.3. Mean percent Japanese honeysuckle cover at Powell County site, Kentucky.

Sample Period*	Summer 05		Fall 05		Summer 06		Fall 06	
Treatments	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Fall								
Control	95	(3.2)	89	(4.6)	95	(1.6)	90	(2.7)
Glyphosate	3.4	(1.0)	2	(1.2)	0.4	(0.4)	1.2	(0.5)
Gly+Ipic	0	(0.0)	1	(1.0)	7	(1.2)	3	(1.2)
Gly+Ipyr	2	(1.2)	3	(3.0)	1.4	(1.0)	11	(1.0)
Imazapyr	2	(2.0)	1	(1.0)	4.8	(1.5)	0.4	(0.4)
Mets+Diflu	2	(2.0)	5	(1.6)	3	(1.2)	4	(1.0)
Tri+Diflu	17	(4.4)	n/a	n/a	56	(6.0)	6	(1.0)
Winter								
Control	95	(3.2)	89	(4.6)	95	(1.6)	90	(2.7)
Glyphosate	2	(2.0)	0.4	(0.4)	3	(1.2)	2	(1.2)
Gly+Ipic	0	(0.0)	9	(2.4)	18	(3.0)	18	(2.0)
Gly+Ipyr	0	(0.0)	0	(0.0)	3	(1.2)	1.8	(0.9)
Imazapyr	0	(0.0)	0	(0.0)	2	(1.2)	2.8	(1.0)
Mets+Diflu	2	(1.2)	0	(0.0)	2	(1.2)	2	(1.2)
Tri+Diflu	27.4	(7.6)	14	(1.9)	44	(7.5)	28	(1.2)
Spring								
Control	95	(3.2)	89	(4.6)	95	(1.6)	90	(2.7)
Glyphosate	2	(1.2)	0	(0.0)	9	(1.9)	3	(1.2)
Gly+Ipic	0	(0.0)	13	(2.0)	16	(4.0)	27	(1.2)
Gly+Ipyr	0	(0.0)	3	(1.2)	2.4	(1.1)	13	(4.9)
Imazapyr	0	(0.0)	1	(1.0)	0.8	(0.5)	7	(1.2)
Mets+Diflu	0	(0.0)	4	(2.4)	1	(1.0)	0.4	(0.4)
Tri+Diflu	12	(3.0)	34	(4.8)	11	(2.9)	47	(8.0)

*For treatments means by sample period, n=5

Appendix III: List of species found at the end of the second growing season by location, season, and treatment.

Table AIII.1. **Hall's Prairie—Fall Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	Toxicodendron radicans	*Passiflora edulis Sims*	*Cirsium Vulgare**	*Solidago altissima*	*Solidago altissima*	*Festuca Arundinacea**	*Acer negundo*
	Rubus spp	*Solidago altissima*	*Solidago altissima*	*Acer negundo*	*Acer negundo*	*Toxicodendron radicans*	*Solidago altissima*
	*Lonicera japonica**	*Toxicodendron radicans*	*Strophostyles umbellata*	*Phytolacca americana L.*	*Erigeron philadelphicus*	*Tridens flavus*	*Rubus spp*
		Campsis radicans	*Phleum pratense **	*Lonicera japonica**	*Cirsium Vulgare**	*Campsis radicans*	*Campsis radicans*
		Hieracium scabrum Michx.	*Toxicodendron radicans*		*Rudbeckia hirta*	*Phleum pratense**	*Passiflora edulis Sims*
		*Lonicera japonica**	*Geranuim carolinianum*		*Erigeron philadelphicus*	*Sorghastrum nutans*	*Lonicera japonica**
			Rubus spp		*Rubus spp*	*Lonicera japonica**	
			*Lonicera japonica**		*Lonicera japonica**		
Native	2	5	5	3	6	4	5
Intro*	1	1	3	1	2	3	1
Total	**3**	**6**	**8**	**4**	**8**	**7**	**6**

Table AIII.2. **Hall's Prairie—Winter Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	Toxicodendron radicans	*Solidago altissima*	*Cirsium vulgare**	*Solidago altissima*	*Tridens flavus*	*Strophostyles umbellata*	*Campsis radicans*
	Rubus spp	*Rumex crispus**	*Campsis radicans*	*Erigeron philadelphicus*	*Toxicodendron radicans*	*Rumex crispus**	*Solidago altissima*
	*Lonicera japonica**	*Monarda fistulosa*	*Erigeron philadelphicus*	*Toxicodendron radicans*	*Campsis radicans*	*Cirsium vulgare**	*Rubus spp*
		Toxicodendron radicans	*Geranuim carolinianum*	*Cirsium vulgare**	*Erigeron philadelphicus*	*Geranuim carolinianum*	*Phytolacca americana L.*
		*Cirsium vulgare**	*Passiflora edulis Sims*	*Phleum pretense**	*Conium maculatum**	*Arenaria serpyllifolia**	*Campsis radicans*
			Solidago altissima	*Acer negundo*	*Geranuim carolinianum*	*Rudbeckia hirta*	*Erigeron philadelphicus*
			Hieracium scabrum Michx	*Geranuim carolinianum*	*Lonicera japonica**	*Lonicera japonica**	*Rudbeckia hirta*
			Rudbeckia hirta	*Rudbeckia hirta*			*Lonicera japonica**
			*Lonicera japonica**	*Lonicera japonica**			
Native	2	3	7	6	5	3	7
Intro*	1	2	2	3	2	4	1
Total	**3**	**5**	**9**	**9**	**7**	**7**	**8**

Table AIII.3. **Hall's Prairie—Spring Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	Toxicodendron radicans	*Solidago altissima*	*Cirsium vulgare**	*Solidago altissima*	*Solidago altissima*	*Passiflora edulis Sims*	*Acer negundo*
	Rubus spp	*Lonicera japonica**	*Campsis radicans*	*Erigeron philadelphicus*	*Acer negundo*	*Toxicodendron radicans*	*Solidago altissima*
	*Lonicera japonica**		*Erigeron philadelphicus*	*Toxicodendron radicans*	*Campsis radicans*	*Acer negundo*	*Rubus spp*
			*Phleum pratense **	*Lonicera japonica**	*Lonicera japonica**	*Monarda fistulosa*	*Cirsium vulgare**
			Toxicodendron radicans			*Arenaria serpyllifolia**	*Conium maculatum**
			Monarda fistulosa			*Campsis radicans*	*Lonicera japonica**
			*Lonicera japonica**			*Lonicera japonica**	
Native	2	1	3	3	3	5	3
Intro*	1	1	4	1	1	2	3
Total	**3**	**2**	**7**	**4**	**4**	**7**	**6**

Table AIII.4. **Shelby County —Fall Treatments**

	Control	Glyphosate	Imazapyr	Glyphosate + Imazapyr	Glyphosate +Imazapic	Metsulfuron+ Difluphenzpyr	Triclopyr+ Difluphenzpyr
	*Lonicera japonica**	*Carduus nutans**	*Solidago altissima*	*Solidago altissima*	*Solidago altissima*	*Conium maculatum**	*Conium maculatum**
		*Coronilla varia **	*Coronilla varia **	*Convolvulus arvensis**	*Coronilla varia **	*Convolvulus arvensis**	*Coronilla varia**
		Solidago altissima	*Asclepias pururascens*	*Coronilla varia **	*Toxicodendron radicans*	*Carduus nutans**	*Carduus nutans**
		*Conium maculatum**	*Conium maculatum**	*Lonicera japonica**	*Lonicera japonica**	*Lonicera japonica**	*Solidago altissima*
		*Lonicera japonica**	*Phytolacca americana L.*				*Rumex crispus**
			*Lonicera japonica**				*Toxicodendron radicans*
							*Lonicera japonica**
Native	0	1	3	1	2	0	2
Intro*	1	4	3	3	2	4	5
Total	**1**	**5**	**6**	**4**	**4**	**4**	**7**

Table AIII.5.. **Shelby County—Winter Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	Lonicera japonica	*Asclepias pururascens*	*Conium maculatum**	*Coronilla varia**	*Coronilla varia**	*Conium maculatum**	*Lonicera japonica**
		*Lonicera japonica**	*Coronilla varia**	*Carduus nutans**	*Carduus nutans**	*Coronilla varia**	
			Solidago altissima	*Solidago altissima*	*Lonicera japonica**	*Solidago altissima*	
			*Lonicera japonica**	*Lonicera japonica**		*Carduus nutans**	
						*Lonicera japonica**	
Native	0	1	1	1	0	1	0
Intro*	1	1	3	3	3	4	1
Total	**1**	**2**	**4**	**4**	**3**	**5**	**1**

Table AIII.6.. **Shelby County —Spring Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	*Lonicera japonica**	*Conium maculatum**	*Conium maculatum**	*Coronilla varia**	*Dipsacus fullonum**	*Campsis radicans**	*Asclepias pururascens*
		*Dipsacus fullonum**	*Rumex crispus**	*Conium maculatum**	*Cirsium vulgare**	*Conium maculatum**	*Phytolacca americana*
		Phytolacca americana L.	*Carduus nutans**	*Campsis radicans*	*Lonicera japonica**	*Rumex crispus**	*Lonicera japonica**
		*Lonicera japonica**	*Dipsacus fullonum**	*Carduus nutans**		*Cirsium vulgare**	
			*Lonicera japonica**	*Lonicera japonica**		*Asclepias pururascens*	
						*Lonicera japonica**	
Native	0	1	0	1	0	1	2
Intro*	1	3	5	4	3	5	1
Total	**1**	**4**	**5**	**5**	**3**	**6**	**3**

Table AIII.7.. **Powell County —Fall Treatments**

	Control	Glyphosate	Imazapyr	Glyphosate + Imazapyr	Glyphosate +Imazapic	Metsulfuron+ Difluphenzpyr	Triclopyr+ Difluphenzpyr
	*Lonicera japonica**	*Toxicodendron radicans*	*Cirsium vulgare**	*Cirsium vulgare**	*Cirsium vulgare**	*Cirsium vulgare**	*Coronilla varia**
	*Coronilla varia**	*Erigeron philadelphicus*	*Convolvulus arvensis**	*Lonicera japonica**	*Coronilla varia **	*Festuca arundinacea**	*Toxicodendron radicans*
	*Cirsium vulgare**	*Festuca arundinacea**	*Lonicera japonica**		*Lonicera japonica**	*Toxicodendron radicans*	*Lonicera japonica**
	Toxicodendron radicans	*Lonicera japonica**				*Lonicera japonica**	
Native	1	2	0	0	0	1	1
Intro*	3	2	3	2	3	3	2
Total	**4**	**4**	**3**	**2**	**3**	**4**	**3**

Table AIII.8.. **Powell County—Winter Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	*Lonicera japonica**	*Toxicodendron radicans*	*Cirsium vulgare**	*Cirsium vulgare**	*Cirsium vulgare**	*Cirsium vulgare**	*Rubus spp*
	Rubus spp	*Coronilla varia**	*Coronilla varia**	*Coronilla varia**	*Coronilla varia**	*Campsis radicans*	*Rhus glabra*
	Rhus glabra	*Cirsium vulgare**	*Lonicera japonica**	*Lonicera japonica**	*Lonicera japonica**	*Lonicera japonica**	*Cirsium vulgare**
		*Lonicera japonica**					*Lonicera japonica**
Native	2	1	0	0	0	1	2
Intro*	1	3	3	3	3	2	2
Total	**3**	**4**	**3**	**3**	**3**	**3**	**4**

Table AIII.9. **Powell County —Spring Treatments**

	Control	**Glyphosate**	**Imazapyr**	**Glyphosate + Imazapyr**	**Glyphosate +Imazapic**	**Metsulfuron+ Difluphenzpyr**	**Triclopyr+ Difluphenzpyr**
	*Lonicera japonica**	*Cirsium vulgare**	*Coronilla varia**	*Rhus glabra*	*Coronilla varia**	*Campsis radicans*	*Rubus spp*
	*Cirsium vulgare**	*Festuca arundinacea**	*Lonicera japonica**	*Toxicodendron radicans*	*Lonicera japonica**	*Cirsium vulgare**	*Coronilla varia **
	*Coronilla varia **	*Lonicera japonica**		*Cardiospermum halicacabum*		*Lonicera japonica**	*Lonicera japonica**
	Rubus spp			*Cirsium vulgare**			
				*Lonicera japonica**			
Native	1	0	0	3	0	1	1
Intro*	3	3	2	2	2	2	2
Total	**4**	**3**	**2**	**5**	**2**	**3**	**3**

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Vita

Education

BS, Zoology - University of Kentucky

BA, American history - University of Kentucky

MA, History with Environmental policy concentration - University of Kentucky

Graduate research: Historic use of Kentucky's natural resources.

MS, Forestry with Conservation biology concentration – University of Kentucky

Graduate research: Natural areas management

Professional Experience

Environmental Biologist Consultant	July 2011 - Present
Kentucky Heritage Land Conservation Fund	Frankfort, KY
Regional Nature Preserves Manager	Nov 2006 – June 2011
Kentucky State Nature Preserves Commission	Frankfort, KY
Park Naturalist II	June 2002 – Nov 2006
Natural Bridge State Park	Slade, KY
Conservation Education Program Leader III	March 1997 - June 2002
Kentucky Department of Fish and Wildlife Resources	Louisville, KY
Research Assistant	Oct. 1996 - March 1997
University of Kentucky Department of Forestry	Lexington, KY
Program Specialist	Aug. 1995 - Oct. 1996
Raven Run Nature Sanctuary	Lexington, KY
Substitute Biology Teacher	Sept 1994 – Aug. 1995
St James School	Elizabethtown, KY

Research Assistant	March 1991 - Sept 1994
University of Kentucky Department of Biology	Lexington, KY

Kentucky Native Plant Society, President	2014 – present
Kentucky Prescribed Fire Council, Steering Committee	2010 - present
Kentucky Native Plant Society, Vice-President/Director	2004 – 2014
Kentucky Society of Natural History, President	2010 – 2012
The Wildlife Society – Kentucky Chapter, Best Student Paper	2006
UK Forestry Graduate Student Association Seminar Committee	2005-2007
Leave No Trace Center for Outdoor Ethics, State Advocate	2004- 2007
Kentucky Association for Environmental Education, Director	1999-2003

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Steen-Ash, S, T.G. Barnes, J.T. Hutchinson, J. L. Larkin, B. E. Washburn, J. L. Weese, H.F Yacek, Jr. 1997. Characteristics of gray squirrel release sites selected by nuisance wildlife control operators. 8th East. Wildlife Damage Management Conf. Roanoke, VA. Available: http://digitalcommons.unl.edu/ewdcc8/31/

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Signature: Jason L. Weese